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DELAYED LEFT EAR ACCURACY DURING CHILDHOOD AND EARLY ADOLESCENCE AS INDICATED BY ROBERTS' DICHOTIC WORD LISTENING TEST[1]

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Summary.—A total of 200 girls and boys between the ages of 6 years and 15 years were administered Roberts' Dichotic Word Listening Test. A statistically significant relatively abrupt and maintained increase in left ear accuracy was noted after 9 years of age (eta = .55). Except for a mild improvement after 6 to 7 years of age, comparable changes were not observed for the right ear. The magnitude of the effect was not significantly diminished even after covariance for verbal fluency and semantic categorization. These results are compatible with the observations that myelination of the cerebral commissures and electroencephalographic phase relations of the right hemisphere achieve near-adult characteristics after 9 years of age. Boys displayed less accuracy for dichotic word listening, particularly for the left ear, compared to the girls (eta = .20).

The use of dichotic listening tasks to infer the potential differential ontogeny of linguistic processing within (Gordon & Zatorre, 1981) or between the temporal lobes (Thatcher, Walker, & Giudice, 1987), has been employed for about three decades. The contributions of age, sex, verbal fluency and the capacity to categorize (Bissell & Clark, 1984; Hynd, Obrzut, Weed, & Hynd, 1979; Kraft, 1982) have been hypothesized as the most common confounding variables associated with the accuracy of dichotic word listening. We designed an experiment to reduce these potential problems by employing an easier dichotic word listening task and by covarying for the subjects' verbal fluency and capacity to categorize objects.

METHOD

Subjects

A total of 200 students, 6 years to 15 years of age, from local primary and secondary schools were selected as subjects. There were 91 boys and 109 girls; 92% of the subjects displayed a right hand preference. About half the number of each sex attended rural schools while the others attended urban schools. Subjects were excluded from this study if (1) they had a diagnosed learning disability, (2) attended schools where the language of instruction was not 100% English (i.e., no French immersion), (3) the family's

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principal language of communication was other than English, and (4) one or more members of the family were fluent in either a second or third language.

Procedure

Each subject was tested individually during a single session (45 min. to 60 min.) in a quiet room within the school setting. After a brief period of rapport, hand preference (writing, scissors, throwing a ball) was determined. Eight percent of the students displayed left hand preference; 4 were boys and 12 were girls. The Roberts' (Roberts, Persinger, Grote, Evertowski, Springer, Tuten, Moulden, Franzen, Roberts, & Baglio, 1994) Dichotic Word Listening Test (Auditec, St. Louis, MO) was administered through stereo headphones (Koss TD60) that were attached to a Sony CFF920 tape recorder. The first 20 trials consisted of monaural practice items (10 words randomly presented to each ear); they were used to ensure appropriate set, understanding of the task and auditory acuity. The subsequent 60 trials were dichotic presentations; the total numbers of correct responses for the left ear only, right ear only, and both ears were measured.

About one minute after the completion of the dichotic word listening task, the subject was asked to say all of the words (except proper nouns) that began with the letters P, C, and S (1.0 min. each). Because there were no major differences in the numbers of words per letter, the three scores were summed to compose the fluency score. The child was then asked to state as many different animals as possible within 1.0 min. These data as well as the subject's age, sex, and hand preference were loaded onto a Vax 4000 computer. All analyses involved SPSS software.

Results

The means and standard deviations for the total numbers of correct responses (of 60) for the right ear, left ear, and both ears for boys and girls for each of the 5 blocks of years (6 to 7, 8 to 9, 10 to 11, 12 to 13, 14 to 15 years) are presented in Table 1. Two way analysis of variance for total correct responses for both ears as a function of age, block, and sex showed that the girls were significantly more accurate than were the boys ($F_{1,190} = 11.87$, $p < .001$; eta = 0.19). *Post hoc* tests indicated that the major age effect ($F_{4,190} = 35.19$, $p < .001$; eta = 0.63) was due to the increase in accuracy that occurred after 8 years to 9 years of age compared to the previous two age blocks. When the variance between numbers of animals stated ($F_{1,188} = 3.18$) and verbal fluency ($F_{1,188} = 1.12$) and dichotically (both ears) correct responses were held constant, the magnitude of the age effect was reduced ($F_{4,186} = 3.47$, $p < .01$; eta = .32) but the effect for sex remained comparable ($F = 11.27$; eta = .19).

TABLE 1
MEANS AND STANDARD DEVIATIONS FOR CORRECT (OF 60) RESPONSES FOR THE LEFT EAR, RIGHT EAR, AND BOTH EARS

Age, yr.	Sex	*n*	Left Ear		Right Ear		Both Ears	
			M	*SD*	*M*	*SD*	*M*	*SD*
6–7	M	22	27.9	11.6	37.3	10.2	17.9	10.0
	F	31	38.9	12.4	40.2	10.7	27.2	11.6
8–9	M	19	38.3	10.2	44.2	10.8	29.3	12.1
	F	24	42.1	7.0	47.5	5.5	34.7	8.0
10–11	M	19	48.4	6.6	47.5	6.3	39.5	8.4
	F	19	50.2	6.5	47.0	7.3	40.1	9.2
12–13	M	17	49.9	4.7	49.1	4.9	41.9	6.3
	F	19	49.1	7.4	50.4	5.9	42.8	9.0
14–15	M	14	47.9	12.6	49.9	10.1	41.1	13.2
	F	16	53.5	4.9	52.0	5.8	47.3	6.9

Three-way analysis of variance (sex, age) with one level repeated (left vs right ear) demonstrated statistically significant differences for the numbers of correct responses (left + right) between ages ($F_{4,190} = 29.20$, $p < .001$; eta = .55). The girls were more accurate than the boys ($F_{1,190} = 9.68$, $p < .01$). There was no statistically significant interaction between sex and age ($F_{4,190} = 1.63$, $p > .05$). The right ear was significantly more accurate than the left ($F_{1,190} = 5.54$, $p = .02$) and there was a highly significant interaction between ear and age ($F_{4,190} = 5.54$, $p < .001$). The interactions between sex and ear ($F = 2.03$) or age, sex, and ear ($F = 1.73$) of subjects were not statistically significant.

Post hoc analyses (Scheffé, $p < .05$) indicated that the major source of the interaction between ear and age was due primarily to the significant and sudden decrease in numbers of left ear errors (increased accuracy) between the children who were 8 years through 9 years of age compared to those who were 10 years of age through 15 years of age. *Post hoc* paired *t* tests also indicated that the right ear was more accurate than the left ear for the 6- to 7-yr.-old group ($t_{52} = 2.26$, $p < .05$) and for especially the 8- to 9-yr.-old group ($t_{42} = 4.35$, $p < .001$); this discrepancy was not observed for either the 10- to 11-yr.-old ($t = 1.62$), 12- to 13-yr.-old ($t = .33$) or 14- to 15-yr.-old ($t = .93$) groups. For the right ear only, the 6- to 7-yr.-old children displayed more errors compared to all other age groups who did not differ significantly from each other.

Because of the heterogeneity of variance for accuracy between the left and right ears and between ages, two-way analyses of variance were completed for the absolute scores and for the square root transformations of these scores for each ear separately. Both absolute and square root-transformed scores for the left ear accuracy displayed statistically significant (*F*s = 28.11 and 23.40; etas = .59 and .56, respectively) age differences. Girls were

significantly more accurate than were the boys ($Fs = 13.29$ and 11.80; etas = .20).

Post hoc analysis indicated that the weak but statistically significant interaction between sex and age ($F_{4,190} = 2.67$ and 2.50, $p < .05$) was due to the greater accuracy for the left ear for the 6- to 7-yr.-old girls compared to the boys of the same age. When the contributions from verbal fluency or numbers of animals reported were removed either singly or as a group, neither the age effect, sex differences nor the interaction between sex and age were modified. Analyses of variance for correct numbers of right ear responses and their square root transformations demonstrated the expected age effect ($Fs = 13.03$ and 9.87; $p < .001$; etas = .46 and .41) but no significant ($Fs = 3.53$ and 3.54; $p > .05$; etas = .10 and .10) sex differences; the interaction between the sex and age was not significant ($Fs < 1.00$).

The means and standard deviations for verbal fluency (sum of numbers of words beginning with P, C, and S) and numbers of animal words are presented in Table 2. Two-way analyses of variance demonstrated significant differences between ages for verbal fluency ($F = 49.32$; eta = .71) and numbers of reported animal words ($F = 37.70$; eta = .66). However, there were neither statistically significant sex differences ($p > .05$) nor interactions between sex and age for any of these measures. It may be of interest, from the perspective of one-tailed tests and previous trends for sex differences, that females displayed higher verbal fluency scores than did the males ($F = 3.04$; $.05 < p < .10$; two-tailed test).

TABLE 2
MEANS AND STANDARD DEVIATIONS FOR SCORES FOR VERBAL FLUENCY AND NUMBERS OF ANIMAL NAMES

Age, yr.	Fluency (Words)		Numbers of Animal Names	
	M	*SD*	*M*	*SD*
6–7	15.8	7.4	11.1	3.9
8–9	23.3	8.8	14.0	3.9
10–11	32.3	7.5	18.1	3.9
12–13	34.5	8.3	20.8	6.2
14–15	38.7	12.1	21.7	6.0
$F_{4,193}$	47.04		37.68	

DISCUSSION

The results of this study compliment and extend the general patterns of ontogenetic change and sex differences in children. A right ear advantage, displayed early in ontogeny, was clearly apparent as reported by Gordon and Zatorre (1981) and Hynd, *et al.* (1979). The differences between girls and boys accommodated only about 4% of the variance. This effect size is similar to previous studies (Bissell & Clark, 1984; Kraft, 1982). Age, analyzed as

yearly increments, explained about two-thirds of the variance for the numbers of errors for words presented to the left and right ears.

From the perspective of cerebral development, the most significant result was the minimal change in accuracy over the age range for words presented to the right ear and the relatively abrupt shift in accuracy for words presented to the left ear between the ages 8 to 9 years and 10 to 11 years. This inflection is consistent with the maturation of the electroencephalographic activity of the right hemisphere reported by Thatcher, *et al.* (1987) and overlaps with the development of connections between the temporofrontal regions of the right hemisphere (Kostovic, Judas, Petanjek, & Simic, 1995), the asymptote of myelination of the corpus callosum (Spreen, Tupper, Risser, Tuokko, & Edgell, 1984) and the interface between the second and third stages of cerebral maturation (Hudspeth & Pribram, 1992).

The absence of a statistically significant effect following covariance for either verbal fluency (a capacity attributed to the prefrontal cortices) or the numbers of names generated for a particular semantic category (a capacity attributed to the temporal lobes) upon the interaction between age and accuracy for the left ear indicates that the effect was not an artifact of linguistic capacity. Because the numbers of axons involved with interconnections between the two hemispheres are at least one order of magnitude less than the numbers of fibers within each hemisphere (Schuez & Preisl, 1996), we suggest that the normal maturation of the corpus callosum and the temporofrontal connections within the right hemisphere facilitates or gates the more efficient arrival and interpretation of right hemispheric acoustic information within left hemispheric awareness.

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